TFL 30 inventory audit

Introduction

An inventory is conducted by the licensee of each Tree Farm Licence (TFL) in British Columbia every 10 to 30 years—using standards and procedures that are approved by the Ministry of Forests—with regular updates to reflect changes in the timber volume due to growth and to depletions from harvesting and natural causes.

This report presents the results of an inventory audit performed within TFL 30. Managed by Northwood Pulp and Timber Limited, TFL 30 is located in the Upper Fraser region of the province, approximately 32 kilometres north and east of Prince George. Encompassing roughly 181 000 hectares of predominantly spruce-balsam forest, TFL 30 extends ninety kilometres from Pass Lake to Summit Lake, on an east-west axis.

Purpose of the audit and application of the results

It is often asked, "How accurate is the current inventory?" To answer this important question, the Ministry of Forests has developed an inventory audit methodology specifically designed to test the overall accuracy of estimates of the total standing volume in each timber supply area.

This inventory audit methodology entails sampling three primary components of the inventory: mature forests, immature forests and non-forest areas.

The objective of the inventory audits program is to help identify TFLs or TSAs where the forest inventory needs attention. Enough samples are taken to ensure statistically reliable results for the TFL as a whole.

The amount of data collected, however, is not sufficient to make statistically reliable conclusions about specific areas or tree species. For example, any overall differences highlighted by the audit could result from problems with one tree species, from part of the land base (such as high elevation rather than lower elevation areas), from one age group of forest stands, or from a combination of these and other factors. As a consequence, general audit results cannot appropriately be used to adjust information about the forests currently available for timber harvesting since this area constitutes only a portion of the total forested area in the TFL.

The audits provide information that may be useful to the chief forester during determinations of the allowable annual cut—offering a general assessment of the uncertainty associated with mature timber volumes, immature site index, and the non-forest classification. However, the audit results cannot justifiably be used to make specific adjustments to growth and yield and other information used in timber supply analysis and allowable annual cut determinations.

Methods

Current inventory

There are 35 TFLs in British Columbia, varying in size from approximately 8 500 ha to just over 1 000 000 ha. Inventories are conducted on each TFL by the licensee through a multistage process. Although the methodology varies within each TFL, all standards must be approved by the Ministry of Forests. New standards currently under development will ensure a consistent minimum standard for all TFLs. Generally, polygons (a boundary drawn around a forest stand of similar characteristics) are first delineated from 1:15 000 or 1: 10 000 scale aerial photographs. Photo-interpretation is then used to produce data on a number of attributes for each polygon. These attributes generally include species composition, stand height, age, and crown closure. Timber volume is then estimated indirectly using the photo-interpreted variables and an empirical yield model. Other approaches to volume estimation, approved by the Ministry of Forests, may also be used.

To keep estimates current, inventories are regularly updated to account for forest growth, and for depletions due to harvesting, fire losses, and the impact of insects and disease. Empirical yield models, such as the Ministry of Forests Variable Density Yield Prediction (VDYP) computer model, are used to update the inventory for forest growth. Field visits, satellite imagery and aerial photographs may be used to update the inventory for depletion.

Inventory audit procedures

The inventory audit tests three components of the current inventory. The first component is the mature forested areas (forest stands greater than 60 years of age). The inventory audit tests the accuracy of the mature timber volume. The second component tested is immature stands (less than 60 years of age but greater than the silvicultural classification of free growing). The audit tests the accuracy of the site growth potential (site index) assignment for these stands. The third audit test is of the photo-classification accuracy of the non-forest classification component of the inventory (areas such as lakes, gravel pits and alpine meadows).

Mature component assessment criteria

Testing the mature component of the inventory compares the existing inventory's estimate of the mean mature volume per hectare for the TFL (called the *inventory volume*), and a new estimate of the mean mature volume per hectare for the TFL obtained from the audit samples (called the *audit volume*).

The difference between these two estimates is called the total bias. A test is conducted on this bias to determine if it is statistically significant. This test establishes whether

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there are detectable differences between the audit volume estimate and the inventory volume estimate, for the total forested area of the TFL.

If the total bias is found to be statistically significant, further analyses are conducted to determine if the specific source of bias within the inventory is one of the following:

- *classification bias:* This is caused by incorrectly estimating the polygon attributes; and
- *model bias:* This is caused by poor prediction from the yield model, which was developed for large areas of the province and was not designed for specific management units.

The analysis to determine the source of bias uses an estimate of the mean mature volume per hectare for the TFL called the *ground attribute volume*. This is calculated from audit sample attributes (stock and stand table estimates of species composition and stocking, and ground-based averages of top height and age), along with crown closure taken from the original map label, using the yield prediction model. The difference between the ground attribute volume estimate and the audit volume estimate approximates the bias associated with the yield model. The difference between the audit volume estimate and the inventory volume estimate not accounted for by the model bias approximates the bias associated with the inventory classification attributes. Once the source is identified, further analyses may be done on the attributes or the model itself.

Immature component assessment criteria

Accuracy of the inventory classification for immature stands is tested by examining the site index assignment. Since the immature forest stand site index provides an estimate of site productivity, its accuracy affects the projection of long-term harvest levels.

Data gathered is examined to determine how closely the audit and inventory site indices match for individual samples, and to explore potential trends.

Non-forest component assessment criteria

The audit test for the non-forest component of the inventory assesses the accuracy of the non-forest classification assignment. An air photo interpreter certified by the Ministry of Forests compares the non-forest inventory classification to a suitably-scaled forest cover aerial photograph. Classification accuracy is rated from a point scoring scheme to determine an overall accuracy percentage. The acceptance criteria for this test is 85% or higher.

TFL 30 audit sampling procedures

The TFL 30 sample was based on files updated from the most recent inventory. A list of all polygons identified on these files was produced and sorted on a number of stand characteristics (site quality, age, and species group). Polygons were systematically selected from this list by a process designed to produce a representative sample of the TFL.

For the mature forested component of the inventory audit, a random sample of 50 forested polygons from the total forested area in the TFL were selected for sampling.

Up to four full-measure prism plots, and five count plots, were established within each of the 50 sample polygons. The plots were located systematically, using a square grid and a random start point. The grid interval distance varied with polygon size. To reduce sample costs for large or irregular polygons, only a randomly selected portion of the polygon was sampled. In total, about 200 full-measure and 250 count plots were established. Field data collection and compilation followed Ministry of Forests cruising and cruise compilation procedures. The objective was to obtain audit volumes that were comparable (in terms of utilization standards and merchantability definitions) to the inventory volumes that are produced by the licensee.

Since the licensee used VDYP as their yield model, the audit volumes were compared with inventory volumes generated using VDYP. The VDYP system produces net merchantable volume per hectare defined as stem volume inside bark of all live trees excluding a 10 cm diameter inside-bark top and a 30 cm high stump. Dead potential and veteran trees are not included in the VDYP system volume estimates. To be consistent with the utilization standards applied by the licensee in their timber supply analysis, the volume was calculated for a utilization standard defined as all live trees of 17.5+ cm dbh (except 12.5+ cm dbh where the leading species on the inventory classification was lodgepole pine). Volumes were compiled net of decay, waste and breakage, as estimated from Ministry loss factors.

The audit volume estimates were then compared to the inventory volume estimates from VDYP to test the validity of the current inventory. Ratios of audit volume to inventory volume were calculated to test for significant differences. The precision of the inventory volume estimates—how well the inventory volume estimate corresponds to the audit volume estimate on a sample by sample basis—were assessed by measuring their statistical correlation. The data was then post-stratified to detect trends related to the operable and inoperable forested land base distribution of the sampled polygons.

From the immature forested component, a random sample of 20 polygons were selected for sampling. Up to six inventory ground calls were established within each of the 20 sample polygons. The plots were located along a single transect line that was considered representative of the site productivity (site index) of the stand. In total, approximately 120 ground calls were established. Field data collection followed the standard Ministry of Forests inventory ground call procedures. The location of the sample transect was subjective. Since the magnitude of bias caused by this process is unknown, the reported results and their interpretations for the immature forested component of the inventory should be used with caution.

For the audit of the non-forest component of the inventory, a random sample of 30 non-forest polygons were selected. Standard Ministry of Forests inventory air photo classification techniques were used to compare the 30 non-forest polygon classification assignments to corresponding air photo checks.

Inventory audit results

Analysis of mature volumes

The results of the inventory audit for mature volume statistical analyses for the total forested area are given in Table 1. Three of the original 50 samples were not included in the analysis when it was determined that these stands were under 60 years of age.

	Audit Volume Estimate	Inventory Volume Estimate	Ground Attribute Volume Estimate
Number of Samples	47	47	47
Mean (m^3/ha)	249	298	273
Coefficient of variation (%)	37	36	38
Standard error	13.36	15.84	14.96
Sampling Error (%)	10.8	10.7	11.0
95% Confidence Interval (m^3/ha)	222-276	266-330	243-303

Correlation coefficient r = 0.433
Ratio of means (audit/inventory volume estimates) = 0.84

Table 1: Statistics for the audit volume, inventory volume and ground attribute volume estimates at 17.5+ cm dbh utilization (except for 12.5+ cm dbh where the leading species was lodgepole pine) less decay, waste and breakage for TFL 30.

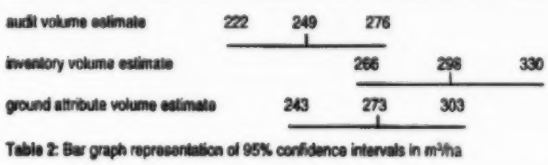

Table 2: Bar graph representation of 95% confidence intervals in m^3/ha

The calculated correlation coefficient of 0.433 for the audit and the inventory volume indicates a good relationship among the individual samples. There is a 49 m^3/ha difference between the means of the inventory estimate for mature volume (298 m^3/ha) and the audit estimate (249 m^3/ha). This difference is statistically significant, 19 times out of 20 for the mature component of the total forested area of the TFL.

Since there was a statistically significant difference between the two estimates, the ground attribute volume was calculated from the VDYP model. The estimated ground attribute volume mean was 273 m^3/ha.

The difference between the ground attribute volume and the audit volume estimates was 24 m^3/ha. The difference between the inventory volume and the ground attribute volume was 25 m^3/ha. This suggests that slightly more of the total bias in the inventory is associated with the inventory attributes.

Analysis of operable and inoperable volumes

To provide audit results more likely to be applicable to the timber supply planning process, an approximation was made of the forested areas considered currently available for timber harvesting (called *operable* areas). The audit results were post-stratified based on this approximation. The results of the inventory audit for samples in the operable forested areas in the TFL are given in Table 3. There were two samples in inoperable forested areas. Because of the high variability and restrictive nature of conclusions associated with this small sample size, volume estimates from inoperable forested areas are not shown.

	Operable Audit Volume Estimate	Operable Inventory Volume Estimate
Number of Samples	45	45
Mean (m^3/ha)	254	301
Coefficient of variation (%)	36	34
Standard Error	13.48	15.43
Sampling Error (%)	10.7	10.3
95% Confidence Interval	227-281	270-332

Operable ratio of means = 0.84

Table 3: Statistics for the operable audit and inventory volume estimates at 17.5+ cm dbh utilization (except for 12.5+ cm dbh where the leading species was lodgepole pine) less decay, waste and breakage for TFL 30.

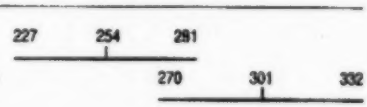

Table 4: Bar graph representation of 95% confidence intervals in m^3/ha for the operable forested area.

For the 45 samples located within the operable forested area, the mean audit volume was 254 m^3/ha and the corresponding inventory volume was 301 m^3/ha. The difference of 47 m^3/ha between the mean audit volume and the mean inventory volume in the operable forested area was statistically significant. The sample size of two in the inoperable forested land base was insufficient to allow any meaningful comparisons to be made.

Analysis of immature inventory classification

Out of 20 stands sampled in the field, two were too young to accurately assess a site index. One stand was not assessed a site index because it was found to be a mature stand. Of the remaining 17 stands, the inventory correctly identified site index within ± 3 m of the audit site index for 11 stands. The inventory site index was more than 3 m lower than the audit site index for four stands, and more than 3 m higher for two stands.

Analysis of non-forested inventory classification

Thirty stands classified as non-forest were assessed for their inventory assignment accuracy. The resulting score was 100%.

Discussion and conclusions

The objective of the inventory audit in TFL 30 was to assess the overall accuracy of the current inventory. The mature, immature and non-forest components were tested.

The results of the audit for the mature component of the inventory suggest that the inventory, using the VDYP yield model, may overestimate volume. Discussions with Northwood staff suggest that since many of the stands in the TFL have lower stocking than the regional average (which is expressed in the VDYP yield model), lower volumes will be more typical of this region.

The licensee has been instructed to incorporate these results as a sensitivity analysis into the current timber supply analysis. The area within TFL 30 has also been designated as the McGregor Model Forest under the Federal-Provincial bilateral agreement. The McGregor Model Forest initiative will develop a computer-based decision support system that fully integrates all resource values into the forest land management planning process. The licensee has agreed to address the inventory issues raised by the audit through the McGregor Model Forest agreement.

Audit results for the immature component of the inventory suggests an acceptable level of accuracy for site index assignment in young stands. The audit assessment of the non-forest classification in this TFL found it to be within provincial standards.

Glossary

accuracy: A measure of the closeness of an estimate to the true value.

allowable annual cut: The rate of timber harvesting specified for an area of land.

analysis unit: The basic building block around which inventory data and other information are assembled for use in forest planning models. Analysis units represent the general level of aggregation, or detail, at which a timber supply analysis is carried out. They are normally defined by tree species and site qualities.

bias: The quality of a measurement device or procedures that tends to result in a systematic misrepresentation of what is being measured.

coefficient of variation: A relative measure of the variation of the population calculated as the ratio between the standard deviation and the mean value.

confidence interval: The range of values within which the population parameter is expected to lie.

confidence level: The estimated probability that a population parameter lies within a given confidence interval.

correlation coefficient: A measure of the relationship between two variables. A value of 0 for the correlation coefficient indicates a random relationship whereas a value of ±1 indicates a perfect positive or negative linear correspondence.

diameter at breast height (dbh): The stem diameter (outside-bark) of a tree measured at breast height (1.3 metres above the point of germination) to the nearest millimetre.

field visitations: Ground level field procedures designed to provide physical verification of polygon inventory attributes.

free growing (crop): A crop of healthy trees of a commercially valuable species, the growth of which is not impeded by competition from plants, shrubs or other trees.

inoperable: Refers to areas having merchantable timber that cannot be harvested economically using current harvesting technology because of some physical barrier (such as a hanging valley), and to areas containing small patches of overmature timber surrounded by large areas of young stands.

mean: The average value of a set of observations.

pre-inventory assessments: Pre-inventory analyses are inventory activities to evaluate the existing forest inventory as the basis for deciding whether to re-inventory or update the current inventory, and to document the existing inventory, maps, and photos to support the execution of the reinventory or update if required.

ratio estimate: The ratio between two different estimates.

representative: The quality of a sample having the same characteristics as the population from which it is selected.

sampling: The process of selecting observations.

sampling error: The error attributed to sampling procedures.

significant difference: An expression used in reference to the results of a statistical test in which either two or more estimates are compared or an estimate is compared to a fixed value. If the observed difference is greater than what might be expected as a chance occurrence due to the sampling procedures, the difference is said to be statistically significant.

site index: A measure of site productivity. Site indices are based on tree height as a function of stand age and are usually expressed graphically as site index curves. A number of site index curves have been developed for British Columbia's major commercial tree species.

standard error: An expression of the absolute variability of an estimate.

standard deviation: A measure of the variation of the population.

timber supply analysis: The technical process of amalgamating land management information into computer systems that predict the amount of timber available for harvest over given time periods.

timber supply area: An integrated resource management unit established in accordance with section 6 of the *Forest Act*.

tree farm license: An integrated resource management unit established in accordance with section 28 of the *Forest Act*.

For more information

For more information or to obtain other inventory audit reports, contact: Director, Resources Inventory Branch, 722 Johnson Street, Victoria, B.C., Canada V8W 3E7, 387-1314, fax 387-5999, or e-mail to RIBinfo@galaxy.gov.bc.ca.